

# **Variability in the Spreading Pathways of the Red Sea and Persian Gulf Outflows**

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## **LONG-TERM GOAL**

Our long-range objective is to understand the mechanisms that affect the spreading and mixing of marginal sea outflows. The Red Sea and Persian Gulf outflows flow over relatively shallow sills at low latitude into a strongly stratified oceanic environment. This makes them unique compared to most of the well-known outflows of the Atlantic Ocean, and valuable “laboratories” for testing ideas about what controls the mixing and spreading of marginal sea outflows.

## **OBJECTIVES**

Our objective are to:

- 1) Describe the synoptic mesoscale circulation in the Red Sea and Persian Gulf outflow regions (Gulf of Aden and Gulf of Oman, respectively) using seasonally repeated AXBT surveys conducted by the US Naval Oceanographic Office (NAVOCEANO).
- 2) Assess the role of mesoscale circulation features in the spreading of Red Sea and Persian Gulf Water.

## **APPROACH**

- 1) Collect all available historical temperature-salinity data from NAVOCEANO's MOODS data archive with the assistance of Mr. Bob Rushton, manager of the data archive.
- 2) Use the historical temperature-salinity data with the AXBT data to map the dynamic height in the Gulf of Aden and Gulf of Oman for each of the AXBT surveys. Data organization will be handled by Ms. Carol Alessi (WHOI).
- 3) Compare dynamic height fields with temperature fields at the equilibrium depth of the outflows to look for impact of mesoscale eddies on outflow pathways. Ms. Alessi and Ms. Heather Hunt will assist with data analysis and interpretation. Guidance from Mr. Jeff Kerling of the Survey Plane Division at NAVOCEANO, who was responsible for the AXBT observations, will also be sought.

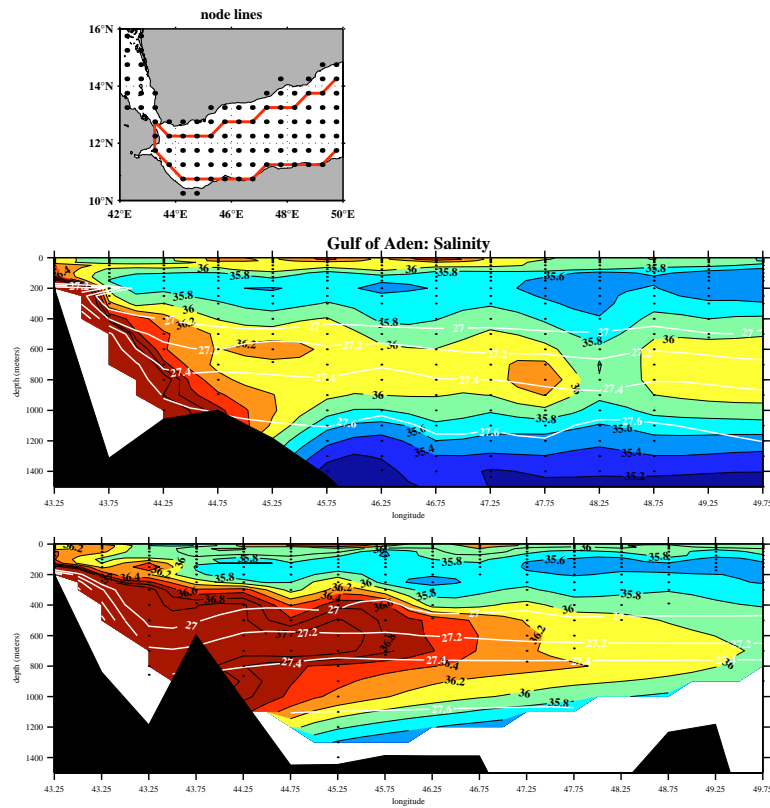
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## WORK COMPLETED

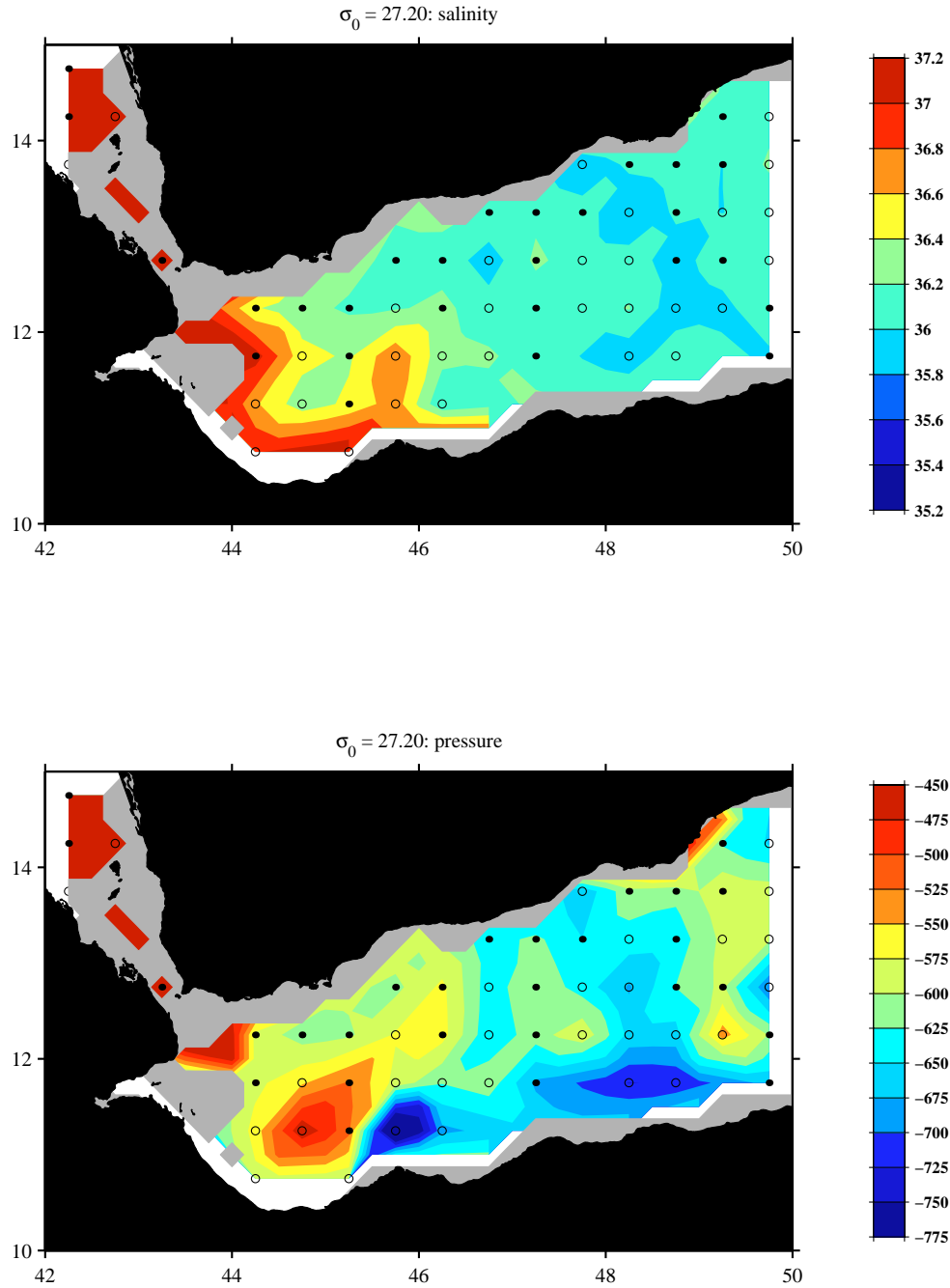
This year we have concentrated on processing and analysis of historical hydrographic data from the Gulf of Aden and Gulf of Oman. We used the quality control procedure outlined in Curry (1996) that was used to quality control the North Atlantic historical hydrographic data. Quality controlling hydrographic observations in a region of strong temporal and spatial variability is quite challenging, and this task took several months. We have used the quality controlled data to examine the hydrographic structure in the outflow regions, and we are working to include these results in the manuscript submitted last year (Bower and Price, 1998). This should help to address the concerns of the reviewers regarding the need to include some salinity observations in the analysis of outflow pathways.

## RESULTS

As a result of our analysis of the historical hydrographic data, we were able to confirm the results from the analysis of the Air-deployed Expendable Bathythermograph (AXBT) data that showed the Red Sea Water and Persian Gulf Water spreading along the continental slopes in narrow veins (boundary currents) to the right of their respective straits. Figure 1 shows this in the vertical plane, and Figure 2 in the horizontal.



**Figure 1: Vertical sections of mean salinity along the northern (upper panel) and southern (lower panel) of the Gulf of Aden. Highest salinities (and warmest temperatures) are found along the Djibouti and Somali coasts. White contours show sigma-theta surfaces.**



**Figure 2: Salinity (upper panel) and pressure (lower panel) on the sigma-theta surface 27.2. Dots and open circles show grid on which data were averaged, the latter indicating less than five observations went into the average.**

Similar results have been obtained in the Gulf of Oman. These results will be used to interpret the synoptic AXBT surveys. We will incorporate our findings into the AXBT manuscript to strengthen our conclusions that Red Sea Water and Persian Gulf Water are transported away from their respective sources largely in narrow boundary currents, much like the transport of Mediterranean Water through the Gulf of Cadiz. We are continuing to investigate the impact of seasonally varying oceanic properties on the product water properties of these outflows.

## **IMPACT/APPLICATIONS**

Our analysis has shown that the Gulf of Aden and Gulf of Oman are characterized by strong spatial and temporal variability of T-S properties due to the spreading of outflow waters. This has important implications for sound propagation in the area. Our continuing data analysis and modeling efforts will shed light on the role of variations in the oceanic environment on the characteristics of outflows.

## **TRANSITIONS**

We continue to maintain an informal relationship and share results with NAVOCEANO through Mr. Jeff Kerling.

## **RELATED PROJECTS**

We continue to discuss our results with Bill Johns, who is analyzing observations from the Bab-al-Mandeb and the Strait of Hormuz collected as part of an ONR-funded program. We have also interacted with Larry Pratt, who is studying hydraulic control in the Bab-al-Mandeb.

## **PUBLICATIONS**

Bower, A. S., and J. F. Price, 1998. The Red Sea and Persian Gulf Outflows. *Journal of Geophysical Research*, submitted.